Large-Area Silicon-Film™ Manufacturing

Highlights

- Reduced the cost of manufacturing modules by 13%
- Increased the production capacity of Silicon-Film™ by a factor of 4
- Achieved a 16.6% efficiency on a 1.0-cm^2 lab cell and 12.2% efficiency on 240-cm^2 solar cell
- Producing AP225 solar cell in a new 9-MW facility; modules will be marketed under the trade name APex™

AstroPower, Inc., is participating in the 1995 solicitation of PVMaT—a cost-shared partnership between the U.S. Department of Energy and the nation's PV industry to improve the worldwide competitiveness of U.S. commercial PV manufacturing.

PVMaT Fact Sheet

Photovoltaic Manufacturing Technology

AstroPower, Inc.

Goal

The goal of AstroPower under the 1995 solicitation of PVMaT was to continue advancing Silicon-Film™ photovoltaic manufacturing technologies, with general objectives to:

- extend continuous processing from sheet fabrication into the solar cell fabrication steps
- reduce the cost per watt of Silicon-Film™ products by increasing device conversion efficiency and by reducing manufacturing costs
- develop new, large-area solar cells
- develop new utility-scale panel products.

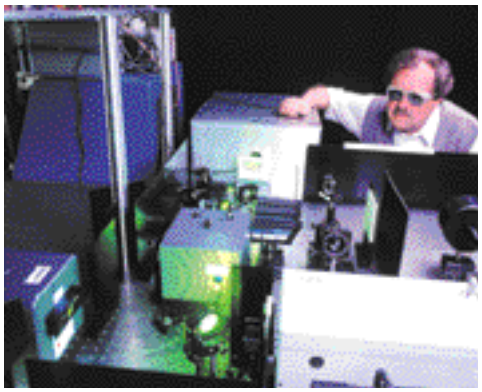
Background

The Silicon-Film™ technology pioneered by AstroPower is based on a process in which a continuous sheet of polycrystalline silicon is generated at a high rate—17 times faster than competing sheet technology. A single Silicon-Film™ machine, in fact, can produce 5 MW of solar cell material per year. Moreover, the cells and modules made with this sheet material promise to be nearly as efficient as those made with competing crystalline silicon technologies. These attributes make Silicon-Film™ a highly promising technology for significantly reducing the cost of PV modules and systems.

To reach this promise, Silicon-Film™ must be improved and moved from the laboratory to production. Such a transition involves three basic development areas. First, the process of generating the sheet material must be optimized to obtain the desired high speed, high quality, and large areas.

Second, the sequence for making solar cells should be optimized to achieve high efficiencies with large areas. Preferably, the process for doing this must be in-line and continuous, rather than batch mode.

Third, these developments must be integrated into an industrial setting by generating and selling significant amounts of solar cells.



Warren Gretz, NREL/PIX04527

The quality of a semiconductor material is crucial to the performance of the final device. AstroPower is testing a technique developed by NREL to evaluate Silicon-Film™ material grown in sheets.

Technical Approach

A key element of developing Silicon-Film™ has been to optimize the geometry of both the sheet and the resulting solar cell.This work initially focused on a nominally 15-cm-wide sheet. Recently, a new machine was constructed that produces sheets greater than 30 cm wide. This machine has been used to produce prototype solar cells with areas of up to 1800 cm^2. In-line solar-cell process equipment has been developed to fabricate these large devices. This new equipment includes an in-line emitter diffusion system (for doping the silicon sheet material to produce the PV effect essential to solar cell operation) and an in-line machine to apply the antireflection coating (which minimizes the reflection of light from the solar cell surface and increases the absorption of light for carrier generation).

This in-line approach has been generalized to “Flexible Manufacturing” for producing solar cells—a concept whereby AstroPower plans to process 30-cm x 120-cm Silicon-Film™ planks using a single set of in-line

equipment.Then, before module assembly, the planks will be cut into various sizes of solar cells to meet market demands.

Silicon-Film™ sheet material gives AstroPower the unique potential to service multiple segments of the solar power market with a stable, high-efficiency, crystalline-silicon product manufactured in a single, integrated production facility.

Results

AstroPower not only met its goal under the 1995 solicitation, but it met every one of its four objectives on the way toward the goal.

Continuous Processing

The company made significant strides in extending its continuous, in-line process from sheet fabrication to processing large-area solar cells and planks. New, continuous processing sequences were developed for gettering, junction formation, and antireflection coating. In each case, new equipment was developed to allow in-line processing of large-area devices. These new processes are being transferred from the laboratory to production.

Cost Reduction

AstroPower reduced the cost of module manufacturing by 13%, with the promise of greater reductions to come as the potential of the improvements are more fully realized. Cost reductions were achieved through several means.

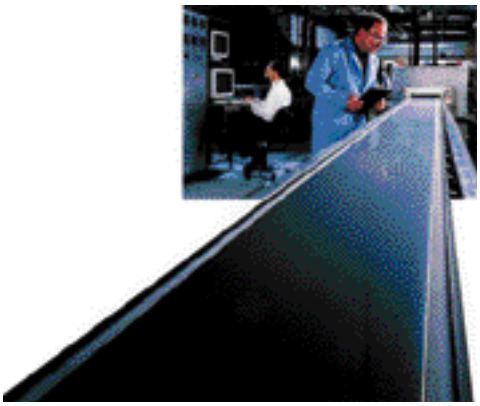
First, by installing a new high-speed machine for processing 15-cm-wide sheets of polycrystalline silicon, AstroPower increased its throughput of Silicon-Film™ by 70%.

Second, by extending the continuous, in-line processing to cell fabrication, the company decreased costs by increasing the efficiency of the fabrication process and by decreasing material costs. This includes a 67% reduction in the cost of chemicals for preparing wafer surfaces.

Third, equipment and process improvements led to higher quality Silicon-Film™ material and to increased solar cell efficiencies. An optimized 1-cm^2 solar cell, for example, achieved a conversion efficiency of 16.6% (measured by NREL).The project goal for this device was an efficiency of 15.6%. Performance on production-sized solar cells (240 cm^2) reached an NREL-verified efficiency of 12.2%.

Large-area Solar Cells

Studies of sheet width have also resulted in constructing a new, wider, Silicon-Film™ machine. This equipment has been used to produce sheets wider than 30 cm. AstroPower used these sheets to make prototype solar cells with areas of 300, 400, and 1800 cm^2. At this time, there is no known limit to the width capabilities of the Silicon-Film™ sheet growth process.



Rusty Ristin/PIX05668

A sheet of thin-film silicon emerges from the growth chamber of AstroPower's manufacturing plant.

Utility-scale Panel Products

A 130-kW array was completed for Niagara Mohawk Power Company (New York).The array uses a new panel product based on AstroPower's 240-cm^2 AP225 solar cell. The new product reduced the array's manufacturing and installation costs. In addition, a new junction box was developed, lowering the cost of this component by a factor of two. Silicon-Film™ solar cells continue to show long-term stability, as evidenced by the performance of the PVUSA array installed in Davis, California, in 1994.

Because of the success of this project, the Silicon-Film™ process is on an accelerated path to large-scale manufacturing.The AP225 solar cell, developed under the PVMaT program, is now being produced in a new 9-MW facility. Silicon-Film™ solar-cell modules will be marketed under the trade name APex™. The first solar cells were produced in this facility in March of 1998.

Company Profile

AstroPower develops, manufactures, markets, and sells PV cells, modules, and panels for generating solar electric power. Solar electricity is used off of the electric utility grid for many applications in the communications and transportation industries and in remote villages and homes. Solar electric power is also used in on-grid applications by existing electric utility customers to provide a clean, renewable source of alternative or supplementary electric power.

In addition to its new APex™ products, AstroPower manufactures and markets conventional single-crystal silicon solar cells and modules worldwide, and it is also developing specialty photovoltaic devices and detectors. Currently the second largest U.S.-owned PV manufacturer, AstroPower is one of the world's fastest growing PV companies.

The company leverages its resources through research and development contracts with government research laboratories and agencies, alliances with corporate partners, and affiliations with strategic customers.

References

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